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Abstract: In this paper we present how context can be used to support an user that is navigating both virtually and physically an information system. Navigation is seen as the act of going from one object to another. Navigation can be virtual like the Web navigation or physical like with a digital museum guide.

We start by giving a formal definition of context that relies on the notion of proximity. An important peculiarity of this definition is that it permits us to build context according to several dimensions at a time, like the thematic dimension, the physical dimension or the temporal dimension. This definition permits us to build two applications that ease the navigation by constantly proposing relevant destinations to the navigating user. The first application is an assistant to help an user that navigates the web. The second application is a digital guide that permits the user to navigate through an information system composed of digital photos.

Key-words: context-aware computing, information systems navigation ,ubiquitous computing

(Résumé : tsvp)

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Utilisation du Contexte pour Combiner Navigation Virtuelle et Physique

Résumé : Dans ce papier nous présentons comment utiliser le contexte pour supporter un utilisateur qui navigue à la fois physiquement et virtuellement. La navigation est vue comme l'acte d'aller d'un objet à un autre. La navigation peut être virtuelle comme sur le Web, ou physique comme avec les guides pour musées.

Nous commençons par donner une définition formelle du contexte qui repose sur la notion de proximité. Cette définition nous permet de construire des contextes selon plusieurs dimensions simultanément, comme la dimension thématique, la dimension physique ou la dimension temporelle. Nous utilisons ensuite cette définition pour construire deux applications qui facilitent la navigation en proposant constamment des destinations pertinentes à l'utilisateur. La première application est un assistant qui aide l'utilisateur lorsqu'il navigue sur le Web. La seconde application est un guide qui permet à l'utilisateur de naviguer à travers un système d'information composé de photos numériques.

Mots-clé : informatique contextuelle, navigation dans un systèmes d'information, informatique diffuse

1 Introduction

Mobile devices such as mobile phones or PDA permit the user to access to information from the physical space. For example, consider a museum guide [2, 12]. This guide delivers information to the user according to the surrounding art pieces. In such a system each art piece is associated with information. The user's location is used to determine the surrounding art pieces and to deliver the corresponding information. As the user moves across the museum, the information presented by the guide is automatically updated, according to her location. We consider that the user goes from one information item to another by physically moving. She *physically navigates* the information system represented by the information associated to art pieces.

Navigating an information system is the act of going from one document to another. A well know information system providing information navigation is the Web. The Web is composed of a set of pages that are linked each other via hypertext links. These links enable the navigation between pages. In contrast to physical navigation, Web navigation is called virtual navigation since the user does not physically moves when she goes from one page to another.

With a modern mobile device the user can access to information systems, especially the Web. When an user accesses to the Web, this access is usually linked to the current activity of the user. For example, when the user is in front of the Eiffel tower, if she accesses to the web, she probably wants to find a web page describing the tower. Starting from this page the user can access to other pages on the Web. Here the physical location of the user can be considered as a starting point to virtually navigate the Web. In order to effectively support the user in such situations, this starting page should be proposed automatically, according to the user's context. Physical navigation enables us to find this starting point automatically. In this case the user discovers information, like web pages, while she physically navigates and she can use these pages to start a virtual navigation.

In this paper we propose to use context to enable a mobile user to easily navigate an information system virtually and physically. We propose a definition of context based on the notion of proximity that permits an user to navigate an information system. Using this definition we can build applications where the user can easily switch between the two navigation schemes. We have used this definition to build two applications: an application that permits the user to physically and virtually browse an information system composed of photos; a navigation assistant supporting an user browsing the Web.

The use of context enables us to propose navigation schemes that require few human computer interactions. Reducing explicit interactions is especially important with mobile devices because they are used in situations where the user already has an activity, like shopping or visiting a city. Therefore, the services offered by the mobile devices must be unobtrusive.

In the next section we present the notion of context and how it can be used for navigation. We formalize the notion of context in section 3. Section 4 presents two applications of this definition. Before concluding we present some related works in section 5.

2 Context

In this paper we focus on the use of context to support an user who is virtually and physically navigating an information system. In this section we present what is context and explain how it can be used to navigate an information system.

2.1 Context and the notion of proximity

To understand the main properties of context we first consider a dictionnary's definition. According to the *Oxford dictionary*, context is :

> *1. the parts of something written or spoken that immediately precede and follow a word or passage and clarify its meaning; 2. the circumstances relevant to something under consideration; out of context without the surrounding words or circumstances and so not fully understandable*

We can extract some fundamental properties from this definition. Firstly, context is a *relative* notion, context is defined according to a reference entity, like a word in a text or an historical event. Secondly, context is a *set* of elements. According to the dictionnary, these elements are determined by a proximity relation. That is, context contains the elements that are close to the reference entity.

In our opinion, the notion which best describes what is context is the notion of proximity: the context of a text passage is composed by the close sentences; the context of a Web page is composed by the pages that are related to this page; the context of a person is represented by the close buildings ...

We choose to define context in this way :

> *Context is defined inside a space composed of elements, like a text or an information system. Inside this space the context of a reference entity is the set of elements that are close to this reference entity.*

In this article we focus on an user who accesses to an information system, so our reference entity will be the user.

2.2 Context and Dimensions

In the preceding section, we have seen that the user's context is a set and that the elements contained in this set are close to the user. Inside an information system, the user's context is the set of documents that are close to him. We determine if a document is close to the user's location according to a precise dimension, like the physical dimension, the temporal dimension or the thematic dimension.

In section 4, we present an application where the user accesses to an information system composed of digital photos. Inside this information system, the user's context is the set of photos that are close to him. If each photo is tagged with the geographical location where it was taken, then we can determine the user's context according to the physical dimension: the user's context is the set of photos that where taken near her. To determine if a photo is close to the user we set a maximum distance. When the distance that separates the user from the photo is below this maximum distance, we consider this photo to be close to the user.

Now, we can also determine the user's context according to another dimension, like the temporal dimension. In this case the photos are tagged with the date they were taken. The user's context is the set of photos that were taken recently. We can even determine the context of the user according to multiple dimensions. For example the user's context can be the set of photos that were taken recently and that are physically close.

2.3 Context and Navigation

We still consider our photos application. In this application the user accesses to the photo set using a mobile device. To ease this access, the user is constantly presented with her context, that is, the photos that are close to her. According to the physical dimension, the user's context is the set of photos that were taken close to her.

If we monitor the user's physical location, then we can automatically update the user's context. Therefore, as she walks the user is automatically presented with physically close photos. When the user's location changes, the context is updated and the mobile device presents the new photos. The user navigates the information system by physically moving. This navigation scheme is called physical navigation.

With physical navigation the user accesses automatically to information that is physically close to her. Physical navigation is useful to the user if the information that is available from her physical location has some semantic link with this location, that is, if the information is physically relevant [9]. In this way, the user accesses to relevant information without having to make explicit searches in the information system.

While she is physically navigating, the photos present in the user's context can also be used as entry points to start a virtual navigation. By selecting a photo present in her context the user virtually moves to this photo's location. According to this new location, we can determine the new user's context. Starting from her new virtual location, the user can select a photo from her new context and move to another virtual location. Using this mechanism, the user can virtually traverse the information system by jumping from one to photo to another. We present in section 4 the practical uses of such virtual navigation.

The figure 1 presents a virtual navigation example. We have a set of 15 digital photos distributed in the physical space. The user is physically navigating this set of photos and her context is the the set of photos located at less than 50 meters of her current location. On the figure the user's physical context contains the photos 5, 7, 9, 10 and 13. From this location she can move to one of the photos present in her context. In this example, the user chooses to virtually move to the photos 7. At this new location her context contains 3, 6, 10 and 11. Then she moves to the photo 11 and so on.

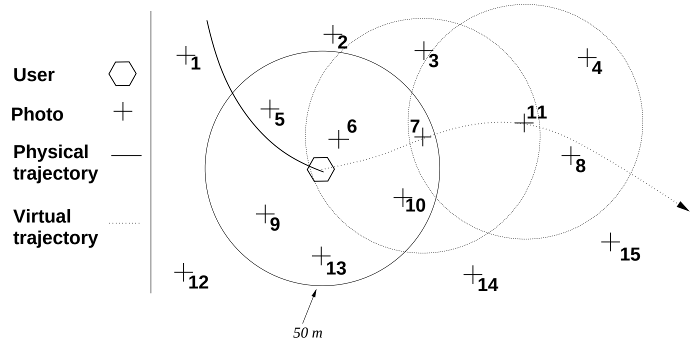

Fig. 1. Example of a virtual navigation through a set of photos

2.4 Common Uses of Context

Context is used in the context-aware computing field to deliver implicit services to the users of mobile devices. The user's context is usually defined as any information item that describes the current situation of the user [4, 6]. This information can include: the temperature, the stress level of the user, the network connectivity of her mobile device, the surrounding objects, the user's location, the user's speed ... Usually, the user's context is used to adapt the service delivered by the application. For example the font size of the screen can be increased when the application detects that the user is running. The user's context can also be used to access to nearby resources like a printer [10] or information items like electronic notes [13].

The notion of context cleary exists in information systems. Consider an user navigating on the Web. This user has a temporal context which is represented by the previously visited pages. She also has a topological context which is represented by the pages that are accessible from the current page. Using the Google search engine [3], we can also determine a thematic context that is composed by the pages that are related to the current page.

Our objective is to enable an user to physically and virtually navigate an information system, using context. We also want to enable the user to switch between the two navigation schemes. Definitions from the context aware field permit us to define context in the physical space, but they are not focused on defining context inside an information system. In this section we have extended the common notion of context, which is based on the notion of proximity, to define context inside an information system, enabling a mobile user to virtually and physically navigate an information system. According to this definition, inside an information system, the user's context is the set of documents that are close to the user. In the next section, we present a formalization of this definition.

3 Formalization

We have introduced our definition of context in the preceding section. Context is defined inside a space that is structured according to one or several dimensions. The central notion to define context is the notion of proximity. In this section we give a formal definition of context. The next section presents applications of this definition.

Context is a notion which is present in several domains, so here we start by giving a general definition of context. Afterward, this definition is applied to an information system and used to define multidimensional contexts.

3.1 Introduction

We want to define the context of an entity. This entity can be a text passage, a person, a Web page, an historical event ... The entity's context is defined inside a space. This space contains elements and the entity's context is represented by the close elements. The nature of the elements depends on the considered space. In a text the elements can be text passages or sentences; people, buildings, objects in the physical space; documents in an information system ...

Proximity is a fuzzy notion, so we chose to say that an element is close to the entity when the distance separating them is below a maximum distance. How the distance between two elements is calculated is dependent on the nature of the space containing them. In the temporal dimension, the distance between two elements is calculated by calculating the difference between the two corresponding dates. In an Euclidean space, like the physical space, the distance is calculated with the common Euclidean distance formula.

3.2 Definition

Let A be a space containing elements e_i of the same kind, where it is possible to calculate the distance between two elements. In this space we want to define the context $C(E)$ of the entity E. For example, if A is the Web, then the e_i are Web pages. E can be a particular Web page, a person surfing the Web, a Web robot ... To construct the context of the entity E, we must be able to calculate the distance between E and the elements e_i. If E is not directly an element of the space A, we consider that there exists an element e_E associated to the entity E. For the Web, the element associated with a person is the page that she is reading.

To calculate the distance between two elements e_i and e_j of A we have the function $d(e_i, e_j)$. The definition of d is not given here, it depends on the nature of the considered space.

Maximum Distance Associated to the Entity The context of E is represented by the set of elements e_i of A whose distance from E is lower than the maximum M :

$$C(E) = \{e_1, e_2, \dots, e_n\} | \forall i, d(e_E, e_i) \leq M \tag{1}$$

For example, A represents the space of restaurants. This space is structured with the physical dimension, thus d is the Euclidean distance function. If we set M to 50 meters, then the user's context $C(E)$ contains the restaurants located at less than 50 meters from the user. Now, we consider that A is the Web and that the elements (Web pages) are organized according to the topological dimension. The distance function d measures the number of links separating the two pages. If we set M to 1, the context $C(e)$ of a Web page e contains the pages that have a direct link to e. Here, "being close to" means having a direct link to.

Maximum Distance Associated to the Elements In the preceding definition we have defined context as the set of elements that are separated from the entity by a distance lower than a maximum M. This definition may not be suited for every situations. Consider an historical event. The context of this event should include the events of minor importance only if they happened in the same time period as the considered event. Similarly, the events of great importance should be included in the event's context even if they happened long time ago. Therefore, if we define the event's context using the definition (1) we can set the maximum distance M to 70 years, however the context will contain a lot of events of small importance that are not related to the considered event. Conversely, we can set the maximum distance to a lower value, but in this case an important event that happened long time ago may not be included in the event context. To address this problem, we propose to associate a different maximum distance M_i to each element e_i:

$$C(E) = \{e_1, e_2, \dots, e_n\} | \forall i, d(e_E, e_i) \leq M_i \tag{2}$$

With this definition an element e_i is included in $C(E)$ if the distance $d(e_E, e_i)$ is below the maximum distance M_i associated to e_i. In this way, we can give a different importance to each event: a battle may have a maximum distance set to several months, whereas a war may have a maximum distance set to several years.

This second definition is useful when each the elements populating the space has a different importance, otherwise the definition (1) is sufficient.

3.3 Context in an Information System

In an information system the user's context contains the documents that are close to her. We can use either the definition 1 or the definition 2 to build the user's context. If all documents have the same importance, the definition 1 is sufficient, otherwise we must use the definition 2.

To build the user context, we must be able to determine the distance between the user and the documents present in the information system. To determine the user's context according the physical dimension, the documents must be associated to a physical location. The distance function is simply the Euclidean distance. To determine the user context according to the thematic dimension, we need a mechanism to calculate the distance between two documents. Such mechanism goes beyond the scope of this paper. We simply suppose that the information system has an ad-hoc mechanism.

3.4 Multidimensional Context

As presented in section 2, context can be determined according to multiple dimensions. We come back to our photos application. Inside the photo space, we choose to represent the user's context by the photos that are physically and temporally close. We consider that each photo has the same importance, so we build the user's context using the definition (1). We apply the definition to each dimension and obtain two photo sets. The user's context is the intersection of the two photo sets.

When the context is determined according to multiple dimensions, we have a set of elements that is close to the user according to each dimension. From these sets, we must determine the final context. According to the application the final context will be the union or the intersection of the sets. In the preceding example we want the photos to be close according to the temporal dimension *and* the physical dimension, so we take the intersection of the two sets. If we want to find photos that are close to the user according to the physical dimension *or* the temporal dimension, then we take the union of the two sets.

Multidimensional context is useful in several situations. Firstly, if only one dimension is used, then the information present in the user's context may not be very relevant for the user. By adding one or several dimensions, it is possible to restrict the content of the user's context and improve its relevance. This is an important point, because if the user's context contains too much information it may become useless. Secondly, the dimensions are named and have a mean for the user. The user can choose the dimension she is following according to her current goal. For example, the user can physically navigate the information system to go somewhere, then she can start a virtual navigation to explore the information system starting from this location.

4 Applications

In the preceding section we have formally defined context. In this section we present two applications which rely on our definition of context: an assistant for web navigation and a virtual guide based on digital photos retrieval. These applications illustrate how context can be used to help users to navigate an information system.

4.1 An Assistant for Web Navigation

We have developed a navigation assistant which permits the user to combine the classical hypertext navigation with a thematic search. This assistant evaluates the thematic context of the user, which is the set of web pages that are thematically close to the current page. When the current page changes, the user's context is updated accordingly. This context is presented inside a dedicated window in the user's web browser. The user's context is built with the definition (1) and the Google [3] search engine. The maximum distance is an internal parameter of the search engine.

With our assistant the user can combine search and navigation. When the user selects a pages from her context, this page becomes the current page, and new pages are proposed. For example, consider a person who is searching a conference in a precise field. She starts on the page of a conference she knows and her context surely contains pages of other conferences in the same field. By jumping from one conference page to another, she can found quickly new conferences. Here, the thematic proximity is used to explore the Web. With our assistant it is possible to directly jump from one page to another even if these two pages are not linked via an hypertext link. That is, our assistant proposes to the user *thematic links* to related Web pages.

Using our assistant the user can control the thematic direction she is taking. For example, when the user is located on the Web site of the French National Art Museum, her context contains links to other museums and other buildings located in Paris, like the Eiffel tower. If the user selects a museum from her context, she knows that she takes the "museum direction" and that her context will probably contain other museums. However, if she chooses the "touristic direction" by selecting the Eiffel tower, she knows that her context will probably contain links to other buildings and touristic attractions in Paris.

Finally, our assistant also reduces the feeling of being "lost in the cyberspace" [7]. With the common navigation scheme the user follows hypertext links to go from one page to another. While the user navigates, she has few information about her current location, except the information provided by the current page itself. She also knows that she arrived to this page from another page, but she does not know the other surrounding pages. Such navigation scheme is like walking in the street with fog; the user knows she is somewhere, but she does not what is close to her. Using our assistant, the user is always presented with pages that are thematically close to the current page, providing further information on her current location. Therefore, during the navigation, the user has a richer representation of her current location inside the Web, reducing the feeling of being lost.

Our assistant is an extension for the Firefox Web browser [1]. Figure 2 presents a screen capture of the assistant when the user is located on the web site of the Scientific American journal. At this location, the user context It is available at http://aces.wiki.irisa.fr/tiki-index.php?page=context+extension.

4.2 Physical and Virtual Exploration of Photo Collections

We have developed a guide to assist mobile users evolving in the physical world. This guide relies on an information system composed of digital photos. Inside this information system, the user's context is represented by the photos that are close to her. The close photos are determined according to the physical dimension and the temporal dimension, so photos are tagged with the location and the time they were taken. The definition (1) is used to build the user's context. The user can set the maximum distance for each dimension and change her temporal location.

Our guide is implemented on a Pocket PC using a GPS receiver to monitor the user's location. The information system is built with a common database that is accessed using a wireless connection. We rely mostly on server side Java technologies for the implementation.

[1] www.mozilla.org

Fig. 2. A screen capture of the context assistant. The user is located on the web site of the Scientific American journal. At this location, the user's context essentially contains links to science related web sites, and particularly links to other journals.

To illustrate the benefits of such guide, we present a scenario showing how it can be used to combine virtual and physical navigation.

Scenario The user starts by physically navigating the information system, so her context contains the photos that are physically close to her. These photos are displayed on the guide's screen. While she moves, the user's context is automatically updated and the changes are reflected on the screen. Therefore the user has nothing to do to access to photos that where taken close to her.

Then, the user arrives in front of a castle. To decide if she wants to visit this castle or not, she starts a virtual navigation. She selects a photo of the castle from her context and the location of this photo becomes her virtual location, she has virtually jumped to a new location. The user's context is updated according to her new location. Thus, the user is presented with new photos; the photos which surround her virtual location. By making some jumps, she can virtually enter the castle and discover the interior. This possibility is especially interesting for buildings that are impossible to visit or to decide to visit or not a monument.

Finally, she decides that she will not visit the castle, but she would like to see it in winter. Therefore, she changes her temporal location and set it to winter to get some photos of the castle covered with snow. Then, she continues her visit with her temporal location set to 1945. Now, while she visits the city, her context contains photos taken just after the second world war, enabling her to virtually visiting the city in the past.

Then, the user arrives at a crossroad and does not know which direction to take. Thus, she switches again to the virtual navigation mode. She selects a photo from her context and makes some virtual jumps in a first direction. Since, she finds nothing interesting in this direction, she tries another one and finds a nice church she wants to visit. Therefore, she decides to take this direction and switch back to physical navigation. In this case, virtual navigation is used to "accelerate" the physical navigation. By making some virtual jumps in the direction she wants, the user can know if the route is sufficiently interesting to be taken.

Interface The left side of the figure 3 presents the photos guide, which is a Pocket PC equipped with a GPS receiver.

The right side of the figure 3 presents the interface of the application. Since the screen of the guide has a limited size, the application presents a maximum of nine photos to the user organized in an array. These photos are located in the array according to the current user's orientation. The photo located at the top of the screen has been taken in front of the user. Similarly, the photo located at the bottom right of the screen has been taken behind the user on his right. Such representation enables the user to precisely know the direction she is following when she virtually navigates. To virtually navigate on the left, the user just has to click on the left photo.

Fig. 3. Left: a photo of the Pocket PC equipped with a GPS receiver and running the photos application. Right: a screen capture of the application showing the physically close photos.

Discussion This guide illustrates the benefits of combining physical and virtual navigation. While she physically navigates the information system the user's context constantly contains physically close photos. At any moment, these photos can be used as starting points for a virtual navigation. A starting point represents a location in the information system that is inside an area of interest, like the physical neighborhood of the user. Starting from this location, the user can explore the area by making virtual jumps to see if there is something interesting. Such search scheme is a relative scheme, in contrast to an absolute search scheme where the user can find information whatever her location is. Google is an absolute search engine. Our guide or our Web assistant are applications which propose a relative search scheme based on starting points.

Our guide improves the perception the user has of her physical environment. Using virtual navigation, the user can accelerate her physical navigation or virtually enter inside buildings. Using a multidimensional context, our guide permits the user to virtually visit a city in the past or during a precise season, just by setting her temporal location and by walking in the street.

With our definition of context, the principle of virtual navigation is the same whatever the considered dimension is. The user is located inside the information system and her context contains the close documents. The user navigates the information system by going from one document to another using the documents present in her context. Consequently, if we add a dimension to an information system, the navigation mechanism of the guide will work with the new dimension with almost no change.

5 Related Works

In 1994, Schilit et al [14] have introduced the term "context-aware" application. For them, three important aspects of context are: where you are, who you are with and what resources are nearby. Moreover, they explain that context is not only limited to the user's location but includes also lighting, noise level, network connectivity ... It even includes the social situation: the user is with his manager or with a co-worker. More generally, context is represented by every physical parameter that keeps the system aware of the state of the environment.

Dey and Abowd [6] explain that common definitions are not sufficiently general to include every information that could be a part of the context. For them:

> *Context is any information that can be used to characterize the situation of an entity. An entity is a person, a place, or an object that is considered relevant to the interaction between the user and an application, including the user and applications themselves.*

The authors explain that if an information can be used to characterize the situation of a participant in an interaction, then this information is context. Chen and Kotz [4] propose a similar definition. Our definition is less general than these definitions, however we believe that it clearly exhibits the relative aspect of context. Moreover, with our definition, it is possible to use context to physically or virtually navigate an information system.

Recently new models of context have been proposed. Padovitz et al [1] have proposed a model of context that relies on a multidimensional space. For them, context is a state, like running or walking. This state is determined using several dimensions, like the speed, the heart rate or the body cardiac rhythm. According to the value on each dimension, the system determines if the user is running of walking. Harvel et al [8] have proposed another multidimensional model of context called context cube. In this model, context is also a state defined according to several dimensions. The authors propose to log the context data and to make offline analysis to extract information from this data, like people co-location in the same room. Our definition also relies on a multidimensional space, but it defines context as a set of elements not as a state.

Previously, we have introduced our definition of context and developed an application relying on a multidimensional context [5]. This application is a virtual museum guide using a context defined according to the physical dimension and the thematic dimension. In this application, the user's context contains keywords and URL that are spread in the physical environment. The URL are directly presented to the user and the keywords are used to find further URL according to the thematic dimension, using Google.

Jones and Brown [9] have introduced a mechanism to use context inside an information retrieval system. This system uses the user's location as a supplementary criteria in the information retrieval mechanism. This work is related to our photos guide since it uses the user's location to retrieve physically close photos.

Tagging photos using geographical coordinates is a hot topic. Among the current projects we can cite the World-Wide Media eXchange project [16] at Microsoft research or the GeoSnapper web site[2]. Both projects propose to index photos using GPS coordinates. Moreover, the World-Wide Media eXchange also envisions the sharing of photos across world-wide users. Our photos application also use photos tagging, however it not only propose to retrieve photos according to a geographical location but also to navigate through a photo set using context.

The Idexis [15]and the SnapToTell [11]projects use digital photos to locate the user inside the physical space. In both cases the user takes a photo and queries the system to retrieve relevant information. In Idexis the objective is to find a relevant web pages according to the photo taken by the user. In SnapToTell the objective is to retrieve touristic information according to the photo.

6 Conclusion and Future Works

In this article we have presented a definition of context based on the notion of proximity. We have presented how this definition can be used to combine virtual and physical navigation. We have illustrated this principle with two applications: a Web assistant which permits the user to navigate the web according to the thematic dimension; a guide which permits the user to virtually and physically navigate through a photos collection.

Coupling physical and virtual navigation permits the user to have a quick access to relevant information. Using physical navigation the user's context always contains documents that are physically close. At any moment, these documents can be used as starting point to virtually navigate the information system. Coupling physical and virtual navigation also permits our photo guide to propose new services, like virtually visiting a city during a different season or virtually entering in closed buildings.

[2] www.geosnapper.com

In our future works, we plan to further develop our photos application. To improve the relevance of the proposed photos, we will use the definition (2) to buid context. Thus, we will have to associate a different maximum distance to each photo. Then, we will focus on the construction of the information system. With the development of mobile devices equipped with a digital camera, a great amount of digital photos is created. Thus, we will study how context can be used to ease the sharing of these photos between users, in order to collaboratively create the information system they will navigate.

References

1. A. Zaslavsky A. Padovitz, S. Wai Loke. Towards a theory of context spaces. In *Pervasive Computing and Communications Workshops PERCOMW'04*, 2004.
2. G. Abowd, C. Atkeson, J. Hong, S. Long, R. Kooper, and M. Pinkerton. Cyberguide: A Mobile Context-aware Tour Guide. *ACM Wireless Networks*, 3:421–433, 1997.
3. Sergey Brin and Lawrence Page. The anatomy of a large-scale hypertextual Web search engine. *Computer Networks and ISDN Systems*, 30(1–7):107–117, 1998.
4. G. Chen and David Kotz. Context Aggregation an Dissemination in Ubiquitous Computing Systems. In *Workshop on Mobile Computing Systems & Applications (WMCSA'02)*, 2002.
5. P. Couderc and M. Banâtre. Spreading the web. In Springer, editor, *Personnal Wireless Communications (PWC'03)*, pages 375–384, 2003.
6. A. K. Dey and G. D. Abowd. Towards a Better Understanding of Context and Context-Awareness. In *Workshop on The What, Who, Where, When, and How of Context-Awareness, Conference on Human Factors in Computing Systems (CHI'00)*, 2000.
7. H. Franz. Drowning in Information when Surfing the Web? Or Going with the Flow . In *33rd Hawaii International Conference on System Sciences HICSS'00*, 2000.
8. L. Harvel., L. Liu, G. D. Abowd, Yu-Xi Lim, C. Scheibe, and C. Chatham. Context Cube: Flexible and Effective Manipulation of Sensed Context Data. In *PERVASIVE*, 2004.
9. G. J. F. Jones and P. J. Brown. Information Access for Context-Aware Appliances. In *SIGIR*, pages 382–384, 2000.
10. T. Kindberg, J. Barton, J. Morgan, G. Becker, D. Caswell, P. Debaty, G. Gopal, M. Frid, V. Krishnan, H. Morris, J. Schettino, B. Serra, and M. Spasojevic. People, Places, Things: Web Presence for the Real World, 2000.
11. J.-H. Lim and J.-P. Chevallet. Snaptotell: Ubiquitous information access from camera. In *Workshop on mobile and ubiquitous information access*, 2004.
12. I. MacColl, D. Millard, C. Randell, and A. Steed. Shared Visiting in EQUATOR City. In *International Conference on Collaborative virtual environments*, pages 88–94. ACM Press, 2002.
13. J. Rekimoto and Y. Ayatsuka. Cybercode: Designing augmented reality environments with visual tags. In *Proceedings of Designing Augmented Reality Environments (DARE'00)*, pages 1–10. ACM Press, 2000.
14. B. Schilit, N. Adams, and R. Want. Context-aware computing applications. In *IEEE Workshop on Mobile Computing Systems and Applications (WMCSA'94)*, Santa Cruz, CA, US, 1994.
15. K. Tollmar, T. Yeh, and T. Darrell. IDeixis - Searching the Web with Mobile Images for Location-Based Information. In *Mobile HCI*, 2004.
16. K. Toyama, R. Logan, and Asta Roseway. Location-Aware Photo Project. www.microsoft.com, 2004.

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